Fiber optics' capacity to provide voice, video, and data signal over telephone and cable networks expands the potential of these networks for education.

state or region (i.e., Comcast, Service Electric, and Parks Cable) are leading the way to interconnecting all local cable *headends* with fiber optic cable (Don Dulchinos, personal communication, June 10, 1994). The regional *hub* and statewide interconnection technology plan has been largely facilitated by CableLabs of Boulder, Colorado, the research and development arm of the cable television industry. This interconnection would serve as a statewide distribution network and enable switching capacity, which will be critical for "on-demand" video services. In addition, interconnection of the individual cable systems provides the potential for using the cable network as a point-to-point communication system comparable to the telephone network. It also facilitates the delivery of distance-learning programming beyond the local loop to other areas in the state or region.

The trend in the cable industry is to install *fiber optic cable* to replace copper coaxial cable. This trend is a result of upgrading, which makes possible some of the new services, such as two-way interactivity, video-on-demand, and voice and data services. Fiber optic cable carries voice, data, and video signals converted into modulated light waves travelling over strands of glass fibers. Fiber has virtually unlimited bandwidth capacity, allowing it to transport tremendous amounts of information. It is currently being used in multiple types of telecommunications systems, including telephone, cable-TV, and data networks.

Fiber cable is a relatively expensive transport system to install because of its fragility (fiber cable can break if it is bent too far) and the necessity to acquire easements to either bury it or hang it on poles (although other wired systems have the same costs). The transmission equipment required to convert voice, video, and data signals into light waves and then back into electronic signals currently is more expensive than the equipment used for other wired systems. However, fiber does allow for multiple signal types to be transmitted simultaneously over long distances without the need for the same level of amplification. In addition, its greater capacity than other transport systems expands its potential uses.

The greatest benefits of cable television include its extensive penetration of homes and schools and its ability to carry multiple channels of voice, video, and data signals. Its limitations include the following: 40 percent of the country does not subscribe to cable services; many rural areas do not receive service; and there is a disparity in system capacity and function from cable provider to cable provider.

Telephone

The telephone system in the United States is used for multiple purposes: carrying voice conversations, delivering text data between computers, sending images over fax machines, and transmitting video images on high-capacity lines. Telephones are often used in distance learning for providing a voice link between the instructor and learners. Combined with modems and computers, the telephone system provides a powerful medium for learning through electronic communication. New compression technologies are allowing more and more data bits to be transmitted over the copper wires that make up much of the "last-mile" system.

Education has not extensively used the telephone as an integral part of instruction because, in large part, the system does not extend into the classrooms of this nation as it does into homes and businesses. Almost every home and business in the country has telephone service, with home penetration rates up to a national average of 95 percent (Belinfante, (1993). K-12 schools, however, where approximately 47 million students and 3 million teachers spend the majority of their day, have minimal phone service. A recent survey estimates a 12-percent penetration rate in the nation's classrooms (Princeton Survey Research Associates, 1993).

The FCC regulates interstate and intrastate toll calls. Intrastate local calls, installation, and monthly access charges are regulated by the PUCs of each state. The PUCs in the past have exclu-

business or residential. The business rate for installation and monthly access in most states is two to three times higher than the residential rate (Organization for the Protection and Advancement of Small Telephone Companies [OPASTCO], 1994). To provide affordable universal service to all homes, telephone companies subsidize the expense of residential service with higher business rates. In most states, educational institutions are charged at the business rate. Some states, such as Texas and Alabama, have recently enacted educational tariffs that allow K-12 educational institutions to pay residential rates for lines that are used for educational purposes.

Frequently, local and regional phone companies exceed the rate of return caps set by the PUCs, resulting in a pool of money that must be rebated to consumers either directly or, with the approval of the PUC, through a public service initiative. Using excess revenues, Rhode Island is currently implementing a three-year pilot project that provides free installation and waives monthly access charges to all K-12 schools in the state. However, the phone lines are only being laid to the building; and schools must bear the cost of taking the lines to the classrooms. The lines can be used only for accessing the Internet or other networks for educational purposes (David LaFrance, Rhode Island Division of Public Utilities and Carriers, personal communication, March 22, 1993). In Michigan, Ameritech has been directed by the PUC to fund distance-learning projects in Michigan schools, using $10.5 million in excess earnings plus another $15.5 million in penalties and interest. Two million dollars will be used to establish a Michigan government television channel, similar in style to C-SPAN; and the remaining funds will be disbursed to schools, based on proposals submitted to the Michigan Council on Telecommunication Services for Public Education (*Heller Report*, 1994b).

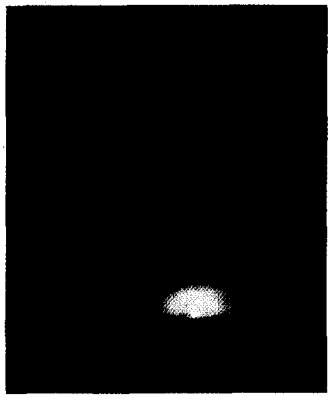
The existing infrastructure, which delivers to homes, businesses, and schools local telephone service provided by the seven Regional Bell Operating Companies (RBOCs) and by more

sists almost entirely of twisted-pair copper wiring. This is a narrow-band conduit with limitations concerning quality and quantity of transmission of advanced digital services. Recent advances in digital compression technologies have resulted in three developments that allow for advanced services to be carried on copper wire: integrated services digital network (ISDN), asymmetric digital subscriber line (ADSL), and high-bit-rate digital subscriber line (HDSL).

ISDN technology transports a digital signal carrying voice, video, or data through the copper wires of today's telephone system. By the end of 1994, it is estimated that almost 60 percent of the nation's telephone access lines will be connected to the digital switching infrastructure needed for ISDN. ISDN can deliver greater interactivity than ITFS or satellite delivered programming, with no added cost to the program (Electronic Frontier Foundation [EFF], 1993). A major test site for ISDN applications to education is currently being operated in North Carolina by Appalachian State University (ASU), AT&T Network Systems, and Southern Bell. The Impact North Carolina: 21st Century Education project's ISDN network delivers interactive video instruction, access to library resources, and professional development programming to elementary and high schools, community colleges, and ASU.

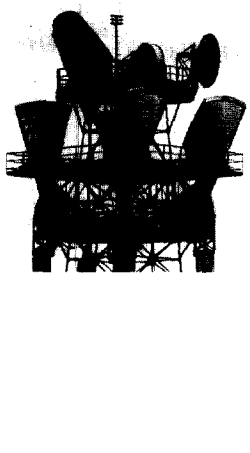
Although ISDN does not offer the speed or capacity of broadband networks, its affordability and the use of infrastructure already in place make it an appealing transition to universal broadband services (EFF, 1993). ADSL and HDSL offer greater broadband capacity than ISDN, capable of delivering full-motion video along with data and voice services.

Whereas most of the local infrastructure is copper wire, most of the long-distance network operated by AT&T, MCI, Sprint, and other smaller carriers is primarily fiber optic cable. Fiber's high capacity allows long-distance companies to carry heavy traffic over a single *backbone* cable that delivers the signal to local or regional switching stations. Although the broad-



transport voice, video, and data simultaneously, a problem arises when the broadband signal attempts to enter the local copper-based infrastructure. It is similar to splicing together a fire hose and a garden hose—as water travels from the fire hose to the garden hose, the volume of water per second that exits the garden hose is greatly reduced over the initial flow rate.

Corning, a major manufacturer of fiber optic cable, estimates that at reasonable substitution rates of fiber cable for copper wire, 93 percent of all U.S. schools, offices and households by the year 2035 will be served by broadband networks at no extra cost to telephone ratepayers. Corning bases its estimates on the average annual expenditures by telephone companies of $18 to $20 billion on building, maintaining, and rehabilitating existing copper telephone lines. If the telephone companies maintain this investment rate, by 2015 the approximately $430 billion spent will almost equal the $450 billion estimated by the Consumer Federation of America to create a fiber network covering the United States. Corning estimates that the United States can achieve the goal of universal deployment by 2015 for an incremental cost of $23 billion (1992 dollars), or 70 cents per telephone subscriber per month for the next 20 years (Suwinski, 1993). One of the disadvantages of using fiber in the telephone system is that unlike copper, fiber requires a separate power source for operating the communication devices. Therefore, when power outages occur, communications will be contingent upon users' abilities to locate separate power sources (i.e. batteries or generators).



The RBOCs have all released statements emphasizing their commitment to providing educational institutions with access to the NII. Pacific Bell recently announced a $100 million initiative to provide every classroom and library with the wiring necessary to access voice, video, and data services. Bell Atlantic is moving forward with its Basic Education Connection, which promises to bring voice and data services to every classroom in its region by the year 2000. One of the critical factors that may influence the RBOCs' commitment to extending the nation's communicatio infrastructure into the classroom is the FC impending ruling on how excess long-distan price-cap revenues must be distributed. The pri cap revenues are a potential funding mechanis for the RBOCs to use without having to ra prices or seek a government tax to pay for bui ing the infrastructure.

Microwave/ITFS

Two types of microwave technologies a now being used. Point-to-point microwave tra mission is a transport system that uses part of t radio spectrum to send either digital or audio s nals between antennas mounted on towers buildings that are usually located from 5 to miles apart and within line of sight. It has t capacity to carry voice, video, and data signa Point-to-point microwave is usually used as pa of a transport system to carry a signal witho burying or hanging wire, or in small (2- or 3-sit networks for voice, video, and data transfer (U Congress, Office of Technology Assessme [OTA], 1989).

The second type of microwave transmissio Instructional Television Fixed Service (ITFS), us microwave transmission in a broadcast mod although it has a more limited range than sta dard broadcast television. ITFS offers an aud return channel but limited capacity for a retu video signal, although compression technologi are capable of realizing that possibility. ITF transmission equipment costs between $20,0 and $30,000 per channel, compared to $80,00 $100,000 for a satellite uplink. A receive antenn capable of receiving simultaneously up to fou channels costs around $150 (Leveille, 1992).

The FCC originally set aside microwave fr quencies for ITFS in 1963 to be used exclusivel for educational and cultural programming. It ha been applied extensively across the United State especially at the higher-education level. For exam ple, ITFS is in use at 16 of 20 California Stat University campuses, with more than 250 receiv sites throughout the state (Leveille, 1992). In th 1980s, the FCC reallocated an unused portion o

the ITFS spectrum for commercial use, creating a flood of commercial entrepreneurs who have quickly filled the spectrum. In many major metropolitan areas, it is now difficult for educational institutions wishing to use ITFS to acquire the needed spectrum. Commercial interest in ITFS has risen since the FCC reallocation. Private wireless cable providers, anxious to increase their channel capacity, have developed partnerships with educational institutions, in which ITFS hardware is provided free to the schools. The wireless cable company, in turn, is able to lease some portion of the four channels allotted per license. According to Theodore Steinke, Chairman and CEO of the National ITFS Association (personal communication, June 13, 1994), other community partnerships allow educational programming during certain times of the day and commercial programming for the remainder.

Because the broadcast range of ITFS is limited to less than 50 miles, it is more predominant in urban rather than rural districts. The line-of-sight requirements make mountainous regions less suitable for ITFS (Wayne Coy, Cohn and Marx law firm, personal communication, June 13, 1994). The ongoing operational costs of providing ITFS services are lower than satellite, as there are no additional charges for ITFS "air time." (Leveille, 1992).

Wireless

New and emerging wireless communications technologies, such as direct broadcast satellite (DBS), broadband radio services, personal communications services (PCS), wireless local area networks (WLAN), and advanced television (ATV), offer the potential for integration into future technology and telecommunications applications in learning and training, with the flexibility of not being tethered to outlets when using communications units such as telephones, fax machines, and computers. Research and engineering studies are being conducted by NTIA's Institute for Telecommunication Sciences to take laboratory and field measurements of advanced wireless communications technologies to help develop and introduce innovative communication systems, including enhanced educational delivery systems.

Cellular mobile communication systems are currently being provided by telephone companies. Increased competition and lower computing costs have resulted in cheaper prices for mobile telephony. Telephone companies expect that advanced digital cellular technology will eventually be as cheap as wireline telephony. Digital cellular technology has the potential for facilitating mobility among computer network users. Some laptop computers already work with wireless modems to transmit and receive data. Some proponents of wireless see it as a viable, inexpensive alternative to fiber for the "last link" of existing communications networks. Potential obstacles to wireless communications involve spectrum availability ("The End of the Line," 1993).

Cellular technology is being used to deliver video signals over short distances. In Brooklyn, New York, "CellularVision" provides subscribers with cable channels by using a six-inch antenna to pick up programs from a microwave transmitter about a mile away. This is a potential solution for combining the resources of broadcast and cable with the local versatility of ITFS. According to CellularVision, a different sort of receiver can provide interactive TV, data transmission, telephone, and voice and video conferencing using the same system. The company's system is based on the same technology as traditional cellular telephone networks, but uses much smaller cells, within a radius of a few miles. The transmitter operates at a low power; but because it operates at high microwave frequencies, it can transmit with a surprisingly wide bandwidth. For crowded urban schools, this type of wireless communication could provide efficient "last link" service without having to wire an entire building ("The End of the Line," 1993).

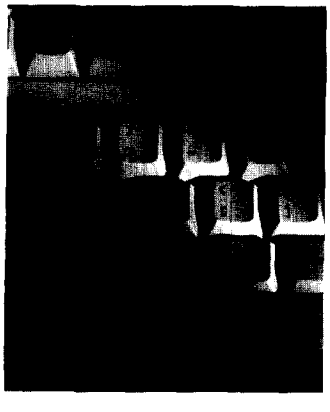
It is expected that wireless technologies will greatly facilitate delivering the NII to learning sites and to rural and inner-city areas lacking wired telecommunications infrastructure. The wiring of some schools, especially older buildings with thick

Wireless technologies may make it easier to deliver the NII to rural and urban learning sites that lack telecommunications infrastructures.

walls and possibly even asbestos, could prove to be prohibitively expensive. In addition, the limited sturdiness of physical connectors to withstand frequent connections and disconnections, as students take tablet-sized computers from class to class, could require frequent repairs. Wires also constrain desks and work areas to fixed locations, and may clutter the classroom environment. The wireless network would overcome these problems by allowing a single wire to be used to connect the wireless network port in each classroom at significant cost savings.

Computer Networking

Multiple technologies are often combined to form a computer network that delivers data, as well as video signals for distance learning. Accessing information and communicating with electronic mail are the primary applications of computer networking for distance learning. An array of systems, including both wired and wireless technologies, are used to connect computers situated within the same building or across the country. Computer networks allow learners to communicate with each other and with available resources by transferring information across distance. Such networks facilitate asynchronous interactions among learners, teachers, and service providers. They encourage collaboration and learner participation, easing the constraints of time by allowing users to customize time frames for thoughtful discussion and response (Mason, 1988; Moore, 1989; Phillips & Santoro, 1989). Some research suggests that using networks may improve skills involving written communication and the organization of ideas (U.S. Department of Education, 1993). Networks can exist internationally, as do the Internet and K12Net, or locally, within a school system or community.



Networks vary greatly in size, scope, and means of transport. Access to a network may occur through ordinary twisted-pair telephone lines; higher-capacity lines, such as T1, T3, or fiber optic cable; or even through microwave or satellite transmission. A network usually has a hub or *server*—a computer dedicated to managing the flow of data between computers on the network. Typically, a user's computer is connected to a network through a *modem,* a device that converts analog and digital signals into text or graphics that are viewed on the computer's monitor. Modems are relatively inexpensive, varying in price according to transmission speed. A 9600 baud (bits per second) modem can now be purchased for under $100, while a 28.8K baud modem costs approximately $500.

The *Internet* is a "network of networks," an electronic pathway for data to travel across the country or around the world. There is no central computer or controlling agency that manages traffic or dictates rules. In many ways, Internet's anarchical structure is both a blessing and a curse (Lewis, P. H., 1994). Advanced users of the system praise its open architecture and the freedom of creativity and expression that stems from the lack of oversight by any public or private censoring groups. Critics of the system cite the lack of structure and oversight as a hindrance to novice and intermediate users who have trouble navigating their way through cyberspace. Teachers, in particular, have complained about the complicated procedures that must be followed to access the Internet (National Coordinating Council for Technology in Education and Training [NCC-TET], 1994). New directories, graphic driven menus, and search tools that are being developed will help users determine what information is available and how to navigate a pathway to a particular source.

Educorp's "Networks Now" survey reports that 38 states have either fully or partially operational networks for instructional services. Ten states reported proposed or planned networks with pending legislation, and one state had no current plans. Twenty-nine states provide educators E-mail access to the Internet, and 20 provide E-mail, file transfer, and telnet access. Composite estimates for the number of users of these *state networks* was reported at over 167,000. With the current growth of networks and Internet connections, the number of users of state networks could reach over 1 million by 1995. Budgets for the state

networks ranged from $50,000 (New Mexico) to $5.3 million (Florida) (Kurshan, Sherman, & Frazier, 1993).

Local area networks (LANs) connect individual machines as a network composed of any number of computers, printers, file servers, CD-ROMs, modems, and fax machines, allowing all of the devices to share digital information. LANs are capable of supporting communication between what were once incompatible hardware brands and models such as Macintosh and IBM-compatible computers. According to 1993 Market Data Retrieval (MDR) research surveys, approximately 40,080 public schools own LANs (49 percent). MDR also projects that 75 percent of all districts will be using LANs by the close of the 1993-94 school year and nearly 100 percent by 1998-99.

Table 1 shows that the number of schools using both internal and external networks also has been growing quite rapidly since 1989. Nonetheless, as Table 1 also suggests, the majority of the schools with LANs are not connected to wide-area or external networks, which would be required to support distributed multimedia distance learning (Newman, Bernstein, & Reese, 1992; Pea, 1994).

The EDUCOM-USC study found that 58 percent of higher education institutions reported a campus backbone network. Of these, 56 percent were fiber optic, 30 percent ethernet, and 12 percent were twisted pair. All institutions with a backbone reported having either an Internet or a Bitnet connection. About half (48 percent) of the institutions had Internet access; however, only 36 percent reported such access for undergraduates, and only 25 percent said that undergraduates used the Internet.

Computers facilitate the electronic storage, retrieval, and computation of information and are often used as tools for accessing electronic networks. Based on recent surveys by the International Educational Assessment (IEA) and the Software Publishers Association, an estimated 4.5 million computers exist in American schools (Anderson, 1993). According to the *Computers in American Schools 1993* study done by IEA, since 1982 the number of computer units in elementary and secondary schools in the United States rose each year by a net increase of 300,000-400,000 units (reflecting discards as well as acquisitions). Between 1989 and 1992, schools added 1.1 million units, increasing their inventory by almost 50 percent, from 2.4 million to 3.5 million computers. Growth was fastest at the upper secondary level.

Table 1
PERCENT OF SCHOOLS REPORTING
USE OF INTERNAL AND EXTERNAL NETWORKS, 1989-1992

Grade Level	1989	1990	1991	1992
Elementary				
Internal (LANs)	8			26
External	-			23
Lower secondary				
Internal (LANs)		17		28
External	-		22	
Upper secondary				
Internal (LANs)		23		41
External	-		34	

Note: LAN = local area network.

Source: Ronald Anderson, personal communication, 1994. See also: Anderson, R. E. (Ed.) (1993). Computers in American schools, 1992: An overview. (IEA Computers in Education Study). Minneapolis: University of Minnesota, Department of Sociology ((909 Social Sciences Building).

The total computer inventory in high schools increased by 57 percent, compared to an increase of about 41 percent in elementary and lower secondary schools. The "typical" high school (i.e., the high school with the median percentage gain) increased its inventory by nearly one half (47 percent) whereas the typical elementary or lower secondary school increased by one-third (32 percent) (Anderson, 1993).

Student-computer ratios (the number of students enrolled in a school divided by the number of computers available for students to use) measure how likely students are to have access on-demand to a school computer. The

U.S. median student-computer ratios based on entire school enrollments are 15:1 for elementary, 14:1 for lower secondary, and 10:1 for upper secondary schools.

Estimates of the number of college and university computers are rough because few institutions have a current inventory of computers. In addition, many faculty and students bring their own computers on campus, which probably would not be indicated in a survey. A survey conducted by EDUCOM-USC obtained estimates on the "number of desktop computers used on campus," and on this basis concluded that in 1991 there were about 2.6 million units (Oveen & Eastman, 1992).

Table 2
Educational Attainment of Computer-Using Workers

Highest Educational Attainment	Percent Using Computers at Work
Not High School Graduate	8.36
High School Graduate	29.81
Some College	50.00
Four Years of College	59.55
More than Four Years College	59.88
Total	38.31

Source: U.S. Department of Commerce, Bureau of the Census. (1989, October). Current Population Survey. Washington, DC: U.S. Government Printing Office.

Good estimates of computer use in adult education programs are unavailable (Anderson, 1993). A recent report published by the Office of Technology Assessment (OTA) (U.S. Congress, 1993) reported, however, that fewer than 15 percent of adult literacy programs use computers regularly in instruction.

According to the U.S. Bureau of the Census, almost 40 percent of U.S. workers use computers in the workplace. There is some indication that workers with more education are more likely to use computers in their jobs (see Table 2) (George, Malcomb, & Jeffers, 1993).

Integration of Technologies

The technologies described in this report are rarely used in a discrete context for distance learning. Rather, multiple technologies are integrated into delivery systems or networks. This trend is being facilitated by the widespread use of digital information, which can be more easily transferred between technologies than the standard analog signals. In addition, because each technology offers unique technical, capacity, or cost benefits, the market is demanding an aggregation of these benefits in distance-learning systems. Combining voice, video, and data into one service does not mean that the service must be delivered using one technology. For example, much excitement exists over the speed and capacity of fiber optics. Indeed, fiber optic cable will play an essential role in delivering distance-learning services and other services on the NII, but there are important roles for the other delivery technologies as well. Integration of technologies is occurring at two levels: delivery systems that transport voice, video, and data signals across distance; and interface units that allow the user to access and transmit signals.

Implementation and integration of various technologies for distance learning and the NII will occur at the federal, state, and local levels and in the private sector. The needs of users and providers and the resources available for implementation vary from home to home, school to school, business to business, community to community, state to state, region to region, and even from nation to nation. Some of the variables that determine this variance include cost, compatibility with previously purchased equipment, geographic impediments (i.e. mountains), distance between the provider and users, number of system users, necessity for monitoring use (for billing and security), and other considerations.

The use of various technologies in distance learning include computers, televisions, VCRs, telephones, fax machines, voice mail systems, computer bulletin boards, and other machines or systems that allow learners and teachers to access, transmit, store, analyze, and compute information. These interfaces, which initially were

designed to perform a distinct task, are continuing to evolve to perform multiple tasks involving information in voice, video, and text formats. For example, computers now not only compute and process numbers and text, but also display video, provide access to information networks, and store voice mail. But even when a technology supports only one function, the current trend in distance learning is to integrate as many of the technologies as necessary for providing interaction and support to learners.

Many distance-learning programs are already using a mix of technologies to best serve their learners. In 1991, community colleges engaged in distance learning reported using an average of 3.7 different technologies for delivery and reception, with an expected growth to 5.6 technologies in 1994. Four-year institutions averaged 3.4 different technologies, growing to 6.1 technologies by 1994 (Brey, 1991).

Many service providers that in the past have transmitted their programming using a primary technology, such as satellite, broadcast, or cable, are moving toward an integrated delivery system. PBS, which traditionally has operated in the broadcast mode, is planning to use multiple delivery systems as they become available and cost-effective. PBS has stated:

> In terms of our own industry infrastructure, satellite is clearly the only universal system, and, because of compression, it's becoming extremely cost-effective. So, for our first mile in reaching our stations across the country, and also taking advantage of the fact that many schools today have satellite dishes—many of them are in areas where there is no cable—we certainly want to use the existing, available technology. But we're already looking at ways that the new fiber network, whether it's owned by the cable companies or the telcos, can be extremely helpful to us in the last mile ("PBS's Educational Satellite Network," 1993, p. 38).

Following are some examples of how technologies are being integrated to better deliver distance-learning services to learners:

- Satellites are currently used to distribute cable television to local providers. Cable systems receive satellite programming, which is then sent over the cable system to the school.

  In Vermont, the Regional Educational Television Network (RETN) uses three cable companies to link nine schools districts serving almost 20,000 students at all grade levels. The districts act as a collaborative to purchase programming from instructional networks—programming that each school district acting as an independent agent may not have been able to afford. For example, RETN pays the Massachusetts Corporation for Educational Telecommunications a $5,000 fee for programming that serves the entire collaborative, a savings of $40,000 if the programming were purchased individually by each district. RETN is planning to add a second channel to each of its school districts, allowing the individual districts to provide local-interest programming, such as school plays or meetings (Smyle, 1993).
- Fiber is currently being used by all of the local and long-distance telephone companies and by many of the cable companies nationwide. It is used mostly as a trunk carrier, receiving and delivering signals fed by either copper wire or coaxial cable. One of the advantages that coaxial cable offers is that it provides a broadband capacity similar to fiber at distances under 300 feet. With over 60 percent of the nation's households and 70 percent of the nation's schools already wired for cable, an integrated fiber/coaxial network could be much cheaper than deploying fiber to every home and classroom.

  An example of the fiber/cable model has been tested in Indiana. The Indianapolis Regional Economic/Academic Development (IREAD) network is a closed-circuit television system operated since 1992 by Indiana Bell/Ameritech, Thompson Consumer Electronics, and Indianapolis Public Schools (IPS). Indiana Bell connected a 600-mile, fiber optic trunk line to 3 administration buildings, 87 schools, and Indiana University-Bloomington. Many of the schools were already wired for cable and

Multiple technologies are usually integrated in distance-learning delivery systems.

were connected to the network using the existing coaxial infrastructure. The network offers voice, video, and data services at a cost of $15,000 per month to IPS (Lewis, J., 1993).

- ITFS serves as a redistribution system in some states, retransmitting satellite, cable, and other signals for broadcast microwave reception. In Detroit, Michigan, the Community Telecommunications Network (CTN) is serving approximately half of the schoolchildren in the state with video programming. CTN operates an ITFS transmit tower north of Detroit that is capable of broadcasting 32 channels up to 50 miles. CTN's Technical Operating Center (TOC) transmits programs originating from videotapes, received by point-to-point microwave, from Michigan Bell's fiber network, or from a Ku/C-band satellite dish (Leveille, 1992).
- The San Marcos Telephone Company of Texas has deployed fiber optic cable to connect three sites near Austin: San Marcos High School, the Gary Job Corps Training Center, and Southwest Texas State University. Although the system is fiber based, it has the capacity to incorporate the telephone, satellite, microwave, and cable systems. Called the TeleCommUNITY Network, the system provides video, voice, and data services not only to students but to members of the community who are enrolled in literacy, adult education, work-skills training, and college-level courses that meet after normal school hours and on weekends. The distance-learning network allows learners at the three sites to take advantage of the combined human and technological resources of all the institutions (Corning, 1993).
- Maine is currently operating a statewide community college system completely using distance-learning resources. Because of the difficult winters and dispersed population, the state decided to deliver two-year associate degrees using a system combining video, audio, and data services delivered to students at learning sites and in their homes. A fiber backbone connects the state colleges and delivers programming to ITFS transmitters that broadcast to learning sites. Audio bridging through NYNEX (a telecommunications system in New York and New England) allows students to interact with the instructor and students at other sites. Computer conferencing and on-line data services are also available (Mayor, 1994).
- The GALAXY Classroom project delivers video by direct broadcast satellite via DirecTv, data and voice transmissions are sent and received by 2-way VSATS, student interaction with the televised "instructors" is accomplished by fax, hands-on learning experiences are provided by accompanying activity kits, and teacher preparation is provided by supplementary print materials. Plans for the 1994-95

Figure 2
Example of CNN Classroom Materials

ANCHOR DESK **December 14, 1993**
(2) TOP STORY RUSSIAN ELECTIONS

1. How do the initial results of the Russian election indicate feelings in the country about economic and social reform? Discuss actions President Yeltsin may choose to take if a Russian parliament predominantly opposed to reform is elected.
2. How can the vote be portrayed as a yearning from the electorate to return to Superpower status? Group students and assign to each group a decade in the 20th Century. Have each group:
a. Research their decade from the Russian point of view, noting what happened in Russia and how changes in Russia influenced world events.
b. Cooperate in writing a series of newspaper headlines, a diary or even a simple dialogue play, fictitiously based on the experiences of a Russian swept up in those events. Have each group perform its work for the class in chronological sequence. Then discuss:
How might the cumulative experiences of the Russian people through the 20th century generations have culminated in Sunday's election results?

RUSSIAN ELECTIONS—WORLD REACTION
3. How might the composition of the new Russian parliament affect international policies toward integrating Russia into the world community? Discuss . . .

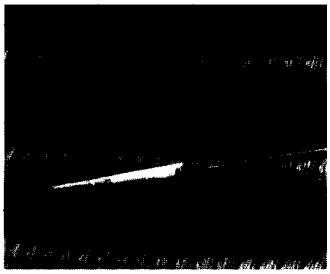
school year include addition of Internet E-mail to enable student interaction with computers

Once the basic equipment—antenna, receiver, TV monitor, and phone line or E-mail for student interaction—has been acquired; schools can set up GALAXY networks according to their needs and facilities. Options include: designing a school hub with classrooms connected to a central computer and with an ethernet network; establishing a media or resource-room connection with a hub computer and a fax machine (or computer for E-mail); or a single monitor and fax machine hooked to a dedicated phone line. According to program materials, equipment costs are estimated at $2,600 per classroom, with an additional $9,950 for the school hub design and $6,500 for the media room design. The single-classroom model does not require additional hub costs, but does require the school to pay monthly phone charges for student fax interaction. According to GALAXY, agreements can be negotiated to rebroadcast the signal in Ku- or C-band uplinks or to use local cable wiring. Subscription costs per student are expected to be comparable to textbook costs, though rates have yet to be finalized (according to materials received from Galaxy Institute for Education, June 1994).

The project offers science and language arts programming to elementary schools nationwide. Current offerings include language arts and science, with mathematics, social studies, foreign languages, and arts programming under development. An independent evaluation of the language arts program concluded that the program, while reaching "diverse multicultural learners in a way that generated extraordinary student enthusiasm," resulted in reading and vocabulary improvements that were significantly greater than in comparable classrooms (Clifford, Guth, & Austin, 1993).

Following are some examples of how user interfaces are being integrated to better deliver services to learners:

- One of the greatest challenges that video-based distance-learning providers and users face is finding a common time that learners and teachers from across the country can participate in a lesson. If interactivity is a desired component, the challenge is expanded. Using VCRs, programs can be recorded for later viewing. This has been especially useful in schools where schedules are difficult to adjust. For example, Ken Burns' (1990) award-winning documentary on the Civil War, an excellent resource for U.S. history classes, originally was broadcast nationally during the evening. The VCR provided teachers with the ability to record the show and incorporate it into their classes when they were ready to use it. Interactivity can be incorporated into recorded programs by establishing "hotlines" that students and teachers can call with questions or using computer bulletin boards for exchanging information. This asynchronous mode of distance learning is becoming increasingly common.
- Interactive video-based programs often use an audio bridge, an operator-assisted telephone line that allows viewers to call in and be connected to the instructor. Cordless phones are frequently used at the receive site so that the phone can be easily and quickly passed to students around the classroom.



PROVIDERS OF DISTANCE-LEARNING RESOURCES

Distance-learning resources consist primarily of video programming (live instruction and prerecorded) and information services (databases). The providers of these resources range from multistate, nonprofit consortiums to independent producers to for-profit information services.

Following is a description of some of the major distance-learning providers:

- The Agricultural Satellite Corporation (AG*SAT) is a four-year-old consortium of land-grant institutions, government, and business and industry. The organizations work together to provide educational services via

satellite for agricultural producers, rural families, and businesspeople, many of whom are in remote or resource-poor areas. Participating offices and institutions are also linking into the Internet computer network, strengthening communication capabilities. Areas of instruction include livestock and crop management, marketing and accounting, child care, nutrition and leadership training, and developments in agricultural research. The combined satellite/computer network has also been instrumental in delivering disaster-relief information quickly and efficiently. AG*SAT's network is made up of campuses and Extension Centers nationwide, usually in rural areas or geographically remote cities, and a Satellite Operations Center at the University of Nebraska. A total of 12 uplinks and 31 receive dishes have been installed, with another 3 uplinks and 178 receive sites planned or under construction. Funding for AG*SAT has been provided by three grants totaling $1.735 million from the U.S. Department of Commerce Public Telecommunications Facilities Program (PTFP) and matching grants from member institutions, local agencies, and states (Randy Brez, AG*SAT Headquarters, personal communication, June 1994).

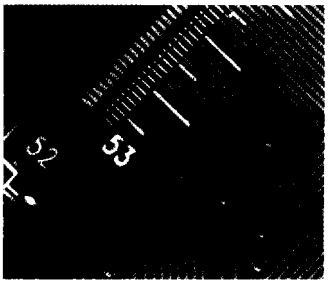
- The Black College Satellite Network (BCSN) provides programming for pre-K through grade 12 and higher education learners and professional development inservice programs for teachers and administrators at all levels. BCSN services 23 states, the District of Columbia, and the U.S. Virgin Islands and has installed more than 1,000 receive dishes nationwide. BCSN is working in partnership with the Central Educational Telecommunications Network (CETN) to deliver programming for the U.S. Educational Network (USEN), a collaborative effort by four major urban school districts (New York City, Philadelphia, Dallas, and Washington, D.C.) to deliver high-quality educational opportunities using shared resources.

  BCSN has trained students and staff at eight historically black colleges and universities (HBCU) to produce video courses for use at the higher education, elementary, and secondary levels. BCSN serves as the distributor for most of the programming produced by the network of HBCUs. During the 1992-93 school year, 20 courses per semester were offered in science, math, and language, totaling about 30 hours of programming per week. An additional series of professional development courses for teachers was offered each semester.
- Cable in the Classroom estimates that during the 1993-94 school year, it has invested $86 million in U.S. schools, including free cable installation to schools and basic service at no cost. Each month, the service provides 525 hours of commercial-free programming available to schools. The programming is donated by over 25 cable networks, such as CNN, Discovery Channel, Lifetime, Mind Extension University, and the Weather Channel.
- The Cable News Network (CNN) Classroom provides daily program guides for their broadcasts over several electronic networks, including gopher, E-mail, and newsgroup feeds. Teachers can read the daily classroom guides, which list the top stories, vocabulary words, handouts, and questions for further discussion. The service is free and exemplifies a basic form of educational multimedia.

  Figure 2 shows an example of the types of support materials supplied by CNN Classroom for use with their daily video broadcasts.
- The Community College Satellite Network (CCSN) is a member-driven coalition of community colleges and educational affiliates serving the needs of its members through the cooperative use of satellite technology. It has been a division of the American Association of Community Colleges since 1989. CCSN offers members a variety of services, including discounts on teleconferences for faculty/staff development, lifelong learning, and continuing education; assistance in

marketing, producing, and coordinating teleconference productions; resources on distance learning technology and information; and participation in a nationally coordinated teleconference downlink network for use by fellow educators, business, government, and community members. Through its activities in coordinating teleconference downlink sites at community colleges, CCSN is attempting to establish a "satellite information infrastructure." Government, business, and industry are using this network to deliver training and information programs via satellite to rural and urban communities throughout the United States (Monica Pilkey, CCSN, personal communication, January 1995).

- Homework Helper is an educational, on-line database service, planned for launch in February 1995. The database will include a vast array of information, including full-text encyclopedias, almanacs, dictionaries, and thesauruses; national and international news wires; full-text newspapers, consumer magazines, "great works of literature," and study guidebooks; standardized exams and tutorials, maps, photographs, and graphics libraries; and basic reference works, including book reviews, movie reviews, and periodical abstracts and indexes. According to Infonautics, its developer, the service will be easier for students to use than some existing services. Rather than rely on Boolean searches or traditional database access languages, users will be able to enter a query in "plain English" and receive bibliographies of relevant resources. The service is expected to be offered to personal computer users through existing network providers, such as Prodigy, for a price of around $10 per subscriber per month. Infonautics suggests that the Regional Bell Operating Companies may begin to offer the service as one of their initial information services. The capacity for localization is an expected benefit to school systems, who will be able to incorporate local materials—such as local newspapers and school curriculum materials—into the service (Patricia Kennedy, Infonautics Corporation, personal communication, June 1994; "An On-Line Library," 1994).
- K12Net is a loosely organized, totally decentralized network of school-based, electronic bulletin board systems throughout North America, Australia, Europe, and Russia, which share curriculum-related conferences or echo forums, making them available to students and educators at no cost and usually on a local phone call. Each system on the network is locally owned and operated, but has access to international telecommunications designed to promote literacy, a global perspective, and competency in 21st century information technologies. In 1990, K12Net projects included a *Holiday Cookbook*, a Weather Project, a "Top Ten" List, a Rivers Project, and the Physics Olympics. Other ideas have included acid rain studies across the continent, market comparisons, role-playing games, and many others.
- KIDLINK is a global program that aims to involve children 10-15 years of age in an international dialogue. In its first two years alone, 6,200 kids from 45 countries participated. The focus is on the actual dialogues between the participants and on how others can join the action. KIDLINK has made available a gallery of digitized artwork from children around the world. The services of KIDLINK are provided free of charge. Global communications projects can influence children's motivation to learn about languages, other cultures, geography, current affairs, environmental awareness, computers, writing skills, word processing, global awareness, history, science, and how participants can virtually travel anywhere they please using networks. A novel-like book is planned for publication based on KIDLINK projects and communications.
- The Massachusetts Corporation for Educational Telecommunications (MCET), chartered in 1982 by the state legislature to bring distance learning to a broad constituency within the state, now serves thousands of learners in more than 37 states with high-quality



Distance learning is being used at all levels of education and instruction, from preschool to worker training, but its use is neither well documented nor comprehensively evaluated.

nstructional programming and support resources. Working with partners in education, business, government, and other fields, MCET operates programs that cover the full spectrum of education:

Mass LearnPike: Mass LearnPike, the centerpiece of MCET's program, is a satellite broadcast network dedicated to improving the quality of K-12 education by expanding curriculum offerings for students and professional development opportunities for teachers. MCET provides member school districts with a steerable, programmable satellite dish, a 27-inch monitor, a VCR, and a portable cordless telephone. It also airs 75 interactive programs that provide instruction in science, mathematics, social studies, geography, history, foreign languages and cultures, dance/music, and literature. Programs are transmitted as one-way video and two-way audio, complemented by hands-on curriculum materials and suggested follow-up activities that have been designed to transform passive viewing into active participation and learning. With the support of local cable operators, Mass LearnPike programs and services now reach more than 325 communities in Massachusetts and schools in 37 other states.

Mass LearnNet: Mass LearnNet is a computer network dedicated to improving communications among educators in Mass LearnPike member schools. The system was designed to be easily accessible by the range of computers now in schools. It is used for sending electronic mail, submitting telecourse registrations, working on joint projects, and continuing conversations initiated during interactive teleconferences. LearnNet also provides a gateway to the Internet, offering access to national and international databases, discussions, and resources. Technical support is provided for users through videos; live broadcasts; hands-on workshops; and on-line, print, and telephone assistance.

The Learning Community: MCET operates The Learning Community (TLC) Project under a two-year, $4.6 million grant from the Star Schools Program sponsored by the U.S. Department of Education. The project, which operates in three demonstration sites—Boston, Hartford, and New York City—uses multiple technologies to promote mathematics, science, and literacy education among children and adults. Through a partnership program, TLC brings schools together with community organizations, human service agencies, local businesses, technical assistance providers, and cable public access stations.

Higher Education Consortium for Distance Learning (HEC): HEC consists of 24 Massachusetts institutions of higher education, both public and private, working collectively to apply advanced technologies to make education more effective. Members have the benefit of sharing courses, teleconferences, and other resources. They also have access to Mass LearnPike for offering programs targeted to K-12 students and faculty and for providing continuing education to industry and the communities they serve. The 1993-94 Mass LearnPike schedule includes 11 HEC programs.

- Mind Extension University (ME/U) provides fully accredited college and graduate-level courses and degree programs via cable television to approximately 25 million households, with plans to expand to 50 million households by 1996. ME/U also cablecasts live, interactive courses for credit at the K-6 level five days a week. ME/U is the only 24-hour cable network delivering distance-learning programming 24 hours a day. Professional development (certification or recertification) is offered.
- National Technological University (NTU) was founded in 1984 to serve the educational needs of highly mobile engineers, scientists, and technical managers. NTU is a consortium of 45 leading engineering schools that provide graduate courses from their respective campuses via instructional television. The majority of NTU students are working professionals, sponsored by their companies. In the past year, NTU enrolled more than

5,000 students in for-credit courses and 100,000 in noncredit courses.

NTU offers courses under several different plans. Programs leading to the Master of Science degree are offered in 11 areas, including computer engineering, hazardous waste management, and health physics. A certificate program is available for students who wish to design their own courses of study to meet specific career needs. NTU also provides a satellite network infrastructure between industry and the university community and offers a videotape instructional service internationally. Courses in the credit sequence are taught by the top faculty of participating institutions. Noncredit courses, symposia, and teleconferences come from a variety of sources, including universities, industry, and other providers.

NTU is not only an accredited university; it is also the world's largest digital television broadcast network. It delivers over 800 graduate courses and continuing education courses by satellite each year via 38 uplinks and 275 downlinks. In 1992, NTU broadcast approximately 23,000 hours of credit courses and 3,000 hours of noncredit courses to 525 sites, including 99 interconnected network sites.

NTU's distance courses soon will be able to take advantage of full integration of video, data, text, and graphics. In the not-too-distant future, NTU's president, Lionel Baldwin, envisions NTU providing individualized instruction delivered directly to the workstation (compiled from materials received from Donald Coffin, NTU).

- PBS distributes its programming to over 300 public television (PTV) broadcast stations around the United States. PBS broadcasts educational programming for younger learners includes *Sesame Street, 3-2-1 Contact, Mister Rogers' Neighborhood,* and a multitude of documentaries on history, science, the arts, and politics. PBS's other video offerings include K-12 Learning Services, Adult Learning Service (ALS), Adult Learning Satellite Service (ALSS), and the Business Channel. PBS is in the process of introducing or testing several computer-based services, including PBS Online, ALS Online, PBS Learning Link, PTV Online, and PBS Mathline.

  PBS has been using satellites since 1978 to relay its signals to its stations and regional networks that broadcast it for open-air reception in their areas. AT&T's launch of Telstar 401 in early 1994 tremendously expanded PBS's capacity to use satellite technology. PBS owns six transponders on the satellite, which with digital compression can carry up to 60 channels. In addition to delivering PBS's package of educational programs (K-12 Learning Services, Adult Learning Service, Adult Learning Satellite Service, and the Business Channel), the satellite provides service for South Carolina Educational Television (ETV), Georgia Public Television, Louisiana Public Broadcasting, National Technological University, Satellite Educational Resource Consortium (SERC), and Satellite Communications for Learning Association (SCOLA). PBS will be offering an array of new video services through Telstar 401 later in 1994, all of which will be supported by PBS Online, a satellite-based computer communications network (*Heller Report,* 1994a).

  To take full advantage of these services, many PBS stations and other downlink sites must retrofit their equipment to receive the compressed video signal from the satellite. PBS anticipates a two-year window before it can put some of its programming, such as the Adult Learning Service, which is downlinked by almost 2,000 colleges, into the compressed format because of the colleges' need to acquire the compression equipment. The compressed programming will allow for greater capacity on the transponders. Currently, because much of the transmission is still analog, no capacity is available. As more of its programming is delivered in compressed digital format, PBS will be able to carry more channels ("PBS's Educational Satellite Network," 1993).
- The Satellite Educational Resources Consortium (SERC) programming serves daily

almost 5,000 students from over 500 schools in 34 states enrolled in high school credit courses, and an additional 75,000 students participating in middle school science programs. The consortium also supports thousands of teachers, administrators, and staff with professional development programming. Sixty percent of the schools receiving SERC programming are classified as rural, 71 percent are eligible for Chapter 1 funds, and 75 percent have fewer than 1,000 students. Credit high school course offerings include precalculus, probability and statistics, calculus, physics, Advanced Placement economics, Japanese, Russian, Latin, German, and Spanish. SERC membership is open to all states. Member states are represented on the board of directors by the chief executive officer of the state public broadcasting entity and the chief state school officer.

SERC is in the process of retrofitting all its downlink sites so that they are capable of receiving compressed digital programming. It is also integrating voice mail conferencing and full Internet capability into its course design because of a recognized need for asynchronous communication among learners, teachers, and program coordinators. SERC recently entered into a five year contract with PBS for transponder space on Telstar 401, realizing $600,000 in savings per year on transponder costs by moving to digital compression, which requires less bandwidth.

- The Satellite Telecommunications Educational Programming (STEP) network is operated by the Educational Service District 101 in Spokane, Washington, and delivers programming nationwide. Fifteen K-12 student courses are offered in Japanese, Spanish, Russian, environmental science, English, workplace basics, Young Astronauts, career paths, middle school science and technology, English as a second language, marine science, and world events. All courses are interdisciplinary in their approach. In 1992-93, almost 2,000 hours of live interactive STEP programming reached almost 15,000 students in 14 states. Access to inservice programming was provided for more than 33,500 teachers. In 1992 there were more than 700 STEP downlink and cable sites. STEP estimates that equipment costs for participating schools range between $5,000 and $10,000.
- The Southern Educational Communications Association (SECA) is a membership organization with 65 public broadcasting licensee members in 20 states. SECA distributes programming, via satellite programming produced by its members, other public television entities, and independent producers, to public television stations nationwide. SECA members receive the programming for free, whereas subscribers pay an annual service fee. SECA also provides feeds of instructional programming each week and administers the National Instructional Television Satellite Schedule, which provides instructional programming to schools.
- Telecommunications Education for Advances in Mathematics and Science (TEAMS) is a service of the Los Angeles County Office of Education. TEAMS focuses on science and math classroom instruction at grades 4-6. Programs use team-teaching techniques that include the classroom teacher and the studio instructor. Professional development occurs at two levels: first, studio instructors model effective instructional strategies during student lessons; second, professional development modules for teachers precede the four-week student instructional module.

TEAMS' latest initiative is the APOLLO 2000 project, serving more than 50,000 students in grades 2-8 across the United States. The project is designed to provide programming that directly supports the National Education Goals, with courses on mathematics, science, literacy, and citizenship skills. APOLLO 2000 is using an integrated network of satellite programming, telephone, computer, and fax communication to achieve interactivity in the learning process and provide adequate support to learners and teachers.

USE OF DISTANCE-LEARNING RESOURCES

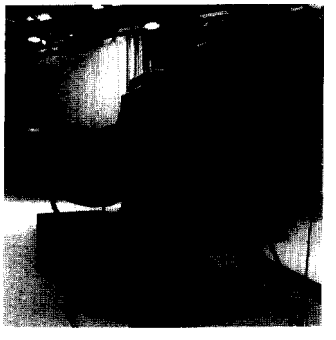
The multiple technologies described above (broadcasting, satellite, microwave, ITFS, cable, telephone, computer networking, and wireless) are being integrated in delivery systems across the country. Learners are using these systems to receive the distance-learning programs of the major service providers, in addition to locally produced classroom instruction and other educational programming. Although comprehensive data concerning the use of distance-learning resources are unavailable, our review of the literature and conversations with experts in the field at the national, state, and local levels revealed that distance learning is being used at all levels of education, from prekindergarten through adult and professional education.

Some attempts have been made to compile statistical data about the users of particular distance-learning technologies and services. For example, the cable industry reports that approximately 34.5 million students nationwide—73 percent of all K-12 students—have access in school to cable programming (Kerns, 1994). Service providers funded by Star Schools grants are estimated to serve 140,000 K-12 students in classrooms across the country (Tushnet, Bodinger-de Uriarte, Manuel, van Broekhuizen, & Millsap, 1993). One aspect of distance learning, video programming, is delivered to users in K-12 schools by a variety of means—in 1992, of the 41 percent of K-12 schools using distance learning, 45.9 percent of video programming was received by satellite dish, 34.8 percent by cable television, 9.6 percent by ITFS, 5.2 percent by fiber optics, and 4.4 percent by copper-based telephone wiring (Quality Education Data, Inc., 1992). A survey conducted in 1991 found that 80 percent of all two-year colleges and 78 percent of four-year colleges and universities anticipated using distance learning by 1994 (Brey, 1991). Almost one-third of Fortune 500 companies report using distance learning for training workers (Portway, 1994). Though confirming that distance learning is occurring nationwide, these statistics do not indicate the number of learners actually using distance-learning services, the ways in which the services are being used, or the frequency of use.

The following examples describe how some users are incorporating various technologies for distance learning produced by major providers and local institutions in K-12 education, higher education, adult education, and the workplace. In most cases, several technologies are integrated to provide complete distance-learning experiences. The descriptions are loosely categorized according to the technology that provides the last link to users.

Broadcasting

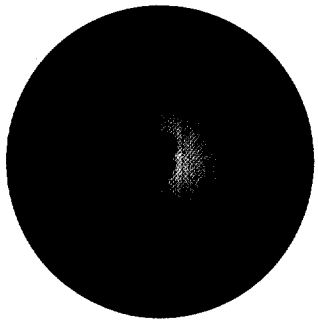
Television broadcasting is typically used for distance learning to reach learners in both homes and schools. It is a one-to-many technology that allows a broadcaster (usually an educational institution or a commercial provider) to distribute a program to many people at the same time, while allowing the learners to be located in different sites. Broadcast distance-learning programs are often called telecourses and usually involve watching a broadcast of an instructor (either live or recorded), completing exercises in a workbook, reading a textbook, and visiting a registered site to be tested. Broadcasting is usually used to reach part-time learners, many of them adults whose busy schedules do not allow them the flexibility of attending classes on a campus at a set time. For example, PBS's Adult Learning Service (ALS), one of the major providers of broadcast telecourses (broadcast locally by public television stations), serves a clientele most of whom work outside the home, are over 35 years old, and have family responsibilities. Almost 80 percent of the of ALS learners are working toward either a graduate or bachelor's degree ("Changing the Face of Higher Education," 1992).



Because the learners receiving distance learning through broadcasting consist of a largely adult population, most of the broadcasters are local stations that work with community colleges, either broadcasting telecourses produced and distributed by a service provider like ALS or broadcasting instruction from their classrooms to

on-site students. For example, Coastline Community College (CCC) in Orange County, California, broadcasts telecourses over KOCE-TV, a licensed public television station owned by CCC. The college broadcasts both telecourses produced by CCC and from service providers such as the Adult Learning Service. Their curriculum committee does extensive review of the telecourses for accreditation. The courses are mainly required introductory courses in a variety of disciplines. They offer 27 telecourses to an average 7,000 students per year, most of whom are working adults trying to return to college. CCC indicates that broadcasting is especially effective for reaching their clientele (Lucy Pascoe, CCC, personal communication, June 3, 1994).

Most broadcast telecourses attempt to provide interactivity between the student and the facilitator. The traditional method of written correspondence has all but been replaced by a variety of telecommunication technologies, ranging from voice-mail applications to group teleconferencing. The use of electronic network discussion groups to provide interactivity for broadcast telecourses is one of the most promising emerging technologies, but providing network access for distance learners remains a difficult challenge (Ted Pohrte, Dallas County, Texas, Community College District, personal communication, June 1994; Neal Sapper, Amarillo (Texas) College, personal communication, June 1994.



Some school districts are also using broadcasting to reach learners who are trying to earn their General Equivalency Diploma (GED). The Granite School District in Salt Lake City, Utah, found broadcasting to be a relatively inexpensive means for offering GED instruction. During the 1990-91 and 1991-92 school years, the school district broadcast seven courses over the local public broadcast station, KULC. The courses, licensed from various producers, ranged in cost from $400 to $1,500 per course. The courses included: (1) Here's to Your Health, (2) Introducing Biology, (3) Earth Revealed, (4) American Adventure, (5) America: The Second Century, (6) Discovering Psychology, and (7) Personal Finance and Money Management. The school district paid $3,000 each year to KULC to broadcast all seven courses for the entire school year (Joe Rickards, Granite School District, personal communication, June 1, 1994).

Radio broadcasting is being used in some areas of the country in a manner similar to telecourses. For example, Wisconsin Public Radio (WPR), one of the largest producers of audio-print courses for higher education, is working with six campus systems served by public radio station licenses to deliver the courses over the air to off-campus students (Dan Peterson, WPR, personal communication, June 1994).

Satellites

Satellite distribution of distance-learning services allows for programming to be received anywhere in the continental United States where users have the proper satellite downlink equipment. Because programming is received directly from the provider and is often used live, satellite-delivered distance learning lends itself particularly well to live interactivity among learners and teachers, approaching the level of interaction often seen in a classroom. Satellite-delivered distance learning typically is used at schools, workplaces, and community institutions where structured educational activities are occurring. It is used in very few homes because of the expense of satellite downlinks.

Distance-learning courses that are distributed live through satellite typically provide interaction between the instructor and learners through the telephone. Learners call into the studio, sometimes through a toll-free number or an audio bridge and ask questions directly to the instructor, who then responds on the air. Some satellite distance-learning providers, such as the GALAXY Classroom project, are providing their students asynchronous interaction through the use of fax and electronic mail (Lori Konopka, Turner Educational Services, Inc., personal communication, May 1994).

Typically, satellite distance learning is used by institutions at all levels of education to provide students with learning opportunities that they

otherwise would not have. For example, in 1990 the state of Kentucky was mandated by court order to rectify the inequities of its education system by using technologies such as those used for distance learning. The state has responded by installing more than 1,700 downlinks sites across Kentucky, including downlinks at every elementary, secondary, and vocational school, community college, and university campus, where students receive the same analog satellite programming from Kentucky Educational Television (KET), which uses a single transponder. Programming ranges from the K-12 level to advanced graduate-degree level. Original programming produced at the University of Kentucky and programming from major service providers, such as SERC, are distributed by KET. In the next few years, KET expects to follow PBS's move to a digitally compressed signal that will allow simultaneous distribution of six channels of programming on a single transponder. The move to compressed digital will require upgrading of all downlinks to handle the digital signal (Nofflett Williams, University of Kentucky, personal communication, June 20, 1994). PBS is currently estimating that the cost of a digital receiver (required to upgrade a downlink) will be approximately $1,800 (*Telstar 401 Update,* 1994).

Satellite distance learning is being used in a similar manner in the state of Mississippi, which has one of the nation's highest illiteracy rates and lowest percentage of high school graduates. Project LEAP (Learn, Earn, and Prosper) uses downlinks sites in elementary and secondary schools to provide job training and GED completion courses to adult learners, many of whom are single mothers receiving public assistance. The downlinks are used during the school day by K-12 students, who receive a variety of programming, including SERC, STEP, and BCSN. The LEAP adult learners have early-morning and evening classes that are transmitted live and provide interaction with the instructor through telephone calls (Ed Meek, University of Mississippi, personal communications, April 1994).

Some corporations such as Hewlett Packard use satellite distance learning to save the cost and time of transporting their workers dispersed around the world to training courses at one site. Hewlett Packard has developed an extensive satellite-delivered distance-learning network for its employees to receive job training at their places of work. Workers from more than 100 classrooms located in company sites around the globe connect to an education network, providing them with video programming from an uplink facility in California and two-way voice communications. Keypad systems in the classrooms allow students to immediately respond to instructors' questions—instructors can monitor the responses and analyze students' level of understanding. Students can also use the keypad to indicate to the instructor that they wish to ask a question. The network allows workers to upgrade their skills and knowledge without leaving their work site, which is both costly and time consuming. Hewlett Packard anticipates in the near future to deliver similar distance learning directly to workers' desks (Portway, 1994). Previously, Hewlett Packard brought all of its sales representatives together for a few days of training each time a new product was introduced, at a cost of $5 million per seminar. Since incorporating distance learning, the cost of each training session has dropped to about $80,000, a savings of over 98 percent (Perelman, 1994).

Hewlett Packard's use of satellite networks saved the company 98 percent of training costs.

Microwave

Point-to-point microwave is typically used as a transport link in an integrated delivery system; however, sometimes it is used to provide small closed-circuit networks that are connecting a limited number of sites. Because microwave is a line-of-site delivery system, each additional receive site added to the network requires the addition of another transmitter at the transmission site. Microwave is easily adapted to a two-way video link by installing a transmitter at the receive site for a return signal. This is the greatest advantage for using microwave as a "last link" delivery system.

Northern Arizona University (NAU) is using microwave to provide a two-way link between classrooms that are participating in live distance learning, where the instructor is teaching a class at

one site and classes at other sites are also participating. The instructor and the students at the other sites can all view one another on video monitors. NAU is producing and delivering more than 25 upper-level undergraduate and graduate courses per semester to rural community colleges around the state using point-to-point microwave for full-voice, video, and data services all on one circuit. NAU transmits an analog microwave signal, which provides broadcast-quality video, and uses two subcarriers for audio and data exchange. The classes are fully interactive, with a 52-inch television and video cameras in each participating class. The microphones in each classroom are voice activated; and the telecourse can distribute up to 150 live microphone signals at one time. All programming on the network is locally produced and is monitored by a single control-room operator, usually a student in the communications or engineering program at NAU. Internal assessment has revealed that students onsite and those participating through distance learning have comparable grades and attendance records. Professors have enthusiastically embraced the system, largely because NAU provides extensive support that adapts the technology to the needs of the instructor (Paul Neuman, NAU, personal communication, June 21, 1994).

Each broadcast-quality classroom costs between $140,000 and $170,000 to build, and the microwave transmission equipment and infrastructure costs approximately $250,000 per site. NAU has spent approximately $3 million and NTIA has contributed almost $1.5 million to build and operate the system. Before the construction of the microwave network, NAU would fly instructors around the state, often 400 or 500 miles, just to teach one course for one day. To lease a T1 data line running from Flagstaff to Yuma, NAU would have to pay $48,000 per year. The cost of using the subcarrier on the microwave network was a one-time expense of $12,000 for two T1 data modems (Paul Neuman, NAU, personal communication, June 21, 1994).

ITFS

When large numbers of users need to be served in multiple learning sites in a region, the omnidirectional nature of the ITFS microwave signal allows for the construction of a single transmitter for delivering distance learning up to about 30 miles without extending the signal. WHRO in Norfolk, Virginia, exemplifies ITFS use for both delivering services directly to users and providing links between other delivery systems such as satellite and cable.

WHRO operates four ITFS channels in Norfolk and an additional two channels in nearby Hampton, Virginia. WHRO gets its feeds by satellite, microwave, cable, and fiber from assorted providers, but the majority of its programming is produced by Old Dominion University, which maintains a fiber optic link with WHRO. WHRO delivers its signals by ITFS directly to elementary and secondary schools and to the headend cable operators for 14 community colleges, colleges, and universities. Programming includes graduate-level engineering, business, and nursing courses otherwise unavailable at the various institutions, and upper-level undergraduate courses that allow community college students to attain their bachelor's degree without leaving their campus of study. Receive sites for these distance-learning courses also include institutions in areas not in proximity of higher education institutions, such as hospitals, museums, and media centers in K-12 schools. WHRO has recently entered into a partnership with a private wireless cable company. In return for WHRO's providing the cable company with an ITFS channel that the station acquired as an educational licensee, the cable company is providing WHRO and some of the educational institutions that use its distance-learning programming with new transmission and reception equipment (John Morison, WHRO, personal communication, June 21, 1994).

One example of WHRO's impact on the region is the delivery of distance-learning programming to the K-12 school on Tangier Island, which lies in the middle of the Chesapeake Bay and is accessible only by boat and airplane. The

school was encountering difficulty retaining qual ified teachers for more than one year and justify ing the cost for small enrollments in certain cours es. The school now uses WHRO's ITFS system (2 way) to offer its students many of the education al opportunities that students on the mainland have. The Accomack Public Schools superintendent, under whose jurisdiction Tangier Island falls, uses the ITFS system to conduct meetings with administrators and teachers on Tangiers Island without requiring expensive and time-consuming travel (John Morison, personal communication, June 21, 1994).

No reliable usage-break-down information exists on the approximately 1,500 ITFS licenses (Theodore Steinke, personal communication, June 13, 1994). ITFS is also being used to link other distance-learning technologies (Leveille, 1992), further complicating usage analysis. A 1991 report of the American Association of Community Colleges (AACC) stated, however, that 16 percent of two-year institutions and 29 percent of four-year institutions were using ITFS systems (Brey, 1991).

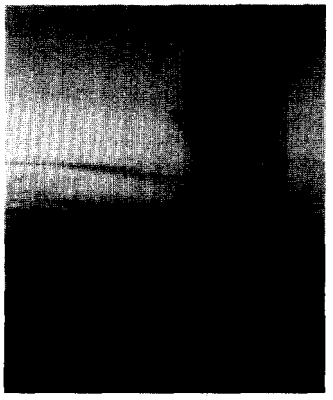
Cable

Cable television can be used both to access major service providers and to distribute local programming. Because many learners have access to cable at both school and home, cable has the ability to reach wide audiences in diverse settings with the same programming. Uses of cable delivery systems for distance learning range from viewing Cable in the Classroom documentaries, to distributing a locally produced course, to experimenting with some of the latest two-way interactive cable systems.

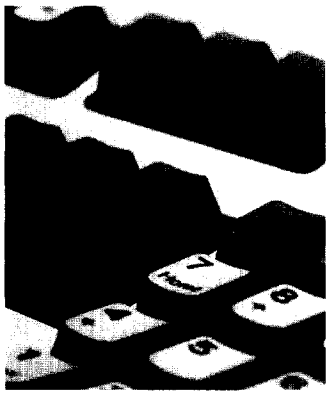
Students in Mason County, West Virginia, who are only a few credits short of high school graduation are using distance learning delivered by cable television to complete the coursework needed for their high school diploma over the summer. Due to budget limitations, the school district had been unable to offer these students summer school classroom instruction. An agreement was

er English, biology, and history courses four days a week for two hours each day on the local cable system. The courses, produced locally by a team of teachers using inexpensive low-end equipment, provide students with the opportunity to continue with their post-high school plans without enrolling for another semester in the fall. Of the 80 students enrolled in the courses in 1993, 63 received passing grades. Mason County plans to incorporate Cable in the Classroom programs for the 1994 courses (Kerns, 1994).

Many people are using the convenience of cable television to watch educational programming and take telecourses, such as the ones developed in Mason County, in their own living rooms. Mind Extension University (ME/U), a national service provider that is carried as a basic service on 895 cable systems reaching 25.6 million households, offers a wide range of high school, undergraduate, graduate, and personal-enrichment classes. Users participating in a degree program enroll with an ME/U affiliated school. Materials that accompany each course are purchased by the user by mail order or, if available, at a local bookstore. Tests are taken at local libraries or schools where proctors registered with ME/U provide supervision. Approximately 7,000 people have enrolled in degree programs through ME/U. An estimated 40,000-50,000 people have participated in the courses, although not necessarily for credit. Because the programming is an open signal, even if a person is not registered for a course, he or she can follow along informally, although no academic credit will be received toward a degree program (Pamela Pease, Mind Extension University, personal communication, May 24, 1994, and June 28, 1994).



The Carrollton School District in Carrollton, Georgia, is actively using cable programming in its curriculum at the K-12 level. As one of the eight demonstration sites for an innovative TeleCommunications, Inc. (TCI) Education project, the district is in the process of integrating its cable network with a fiber optic data network. Working with TCI, each classroom in the



cable and fiber networks that carry video and data. TCI is in the process of wiring the homes of students determined to be "at risk," allowing parents and students in these homes to receive local educational programming that is targeted directly at these families (NCTA, 1993b, pp. 6, 17). TCI is planning to offer a video service to all homes in the Carrollton School District that will allow parents to interact with their children's teachers and find out information about educational performance. Although the school district uses educational programming from service providers, it is also generating some of its own programming. Through a special agreement with Cable News Network (CNN), the school district receives a raw video feed from CNN, which is in turn edited and produced into a local news show by Carrollton High School students. The program is then sent over the cable system to the entire community. Since Carrollton School District first implemented its cable network, along with other technologies, the high school dropout rate has decreased from 28 percent to less than 5 percent. The school credits the use of telecommunications technologies as an essential component for achieving this positive step (Robert Hendrick, Carrollton School District, personal communication, June 28, 1994).

As with other educational programming, cable providers of distance learning are also attempting to incorporate interactivity into the learning experience. In an innovative combination of live cable and electronic networks, Turner Broadcasting has begun to offer live "electronic field trips." Teachers and students watch live educational programming while interacting with each other and on-site experts through toll-free phone lines and America Online discussion groups (Lori Konopka, CNN Public Relations, personal communication, May 1994).

Telephone

The telephone system is typically used for distance learning as a means for providing a voice return to an instructor who is being viewed by students through an alternative means of video delivery and as a connection to on-line computer services. For example, the Backus Elementary School in the District of Columbia is one of the many sites around the country using TEAMS's math and science programming delivered via live satellite feed. Students interact with their instructor by dialing a toll-free number during the live program. Some innovative uses of voice information services, such as voice mail, are underway around the country. Recent developments in compression and switching are allowing for the compilation of voice, video, and data signals of distance-learning programming, all on standard copper telephone lines.

Impact North Carolina: 21st Century Education is a comprehensive plan to help schools take advantage of multimedia distance-learning experiences using ISDN and the existing copper-wire telephone network. The Watagua School District in Boone, North Carolina, is using the network to provide two-way videoconferencing and data exchange among Watagua High School, two elementary schools, and Appalachian State University. Each of the four sites maintains three ISDN lines. One is connected to the file server of a local area network, using the university's ethernet backbone and providing access to on-line library resources and electronic mail. As a result, electronic communication is often used along with the videoconferencing services to provide richer learning experiences. For example, students collaborate on a project with other classrooms, using electronic mail, and present the final results of their efforts during videoconferences. Another ISDN line is connected to a multimedia workstation, allowing users to take advantage of dynamic graphic capabilities that are often incorporated into the videoconferencing presentations. The third ISDN line is connected directly to the videoconferencing equipment. This includes two viewing monitors and an overview monitor for displaying documents and objects, all coordinated using a wireless remote control (Riedl & Carroll, 1993).

Individual students and entire classrooms communicate with each other and with the university. High school students regularly develop interactive presentations for elementary students, and elementary students from the two schools collaborate on science experiments. These services are available to all teachers and students. Watagua also receives professional development programming and conferencing services from the Texas Interactive Instructional Network (TI-IN). Future plans include adding schools in six other counties to the network. Teacher training, a flexible communications system with a variety of learning options, and a designated network service coordinator have been important aspects of the technology use (Patty Blanton, Watagua High School, personal communication, June 1994; Riedl & Carroll, 1993).

Computer Networking

Students are using computer networking to access and share resources, information, and instruction across distance, creating virtual learning envoronments. Typically, computer networking is used primarily as a secondary form of interaction in support of distance-learning programming. For example, MCET's Learn NET allows learners and teachers to access support materials, exchange information, and participate in on-line activities coordinated with MCET's video programming.

Some schools are using computer networks as the hub for technology resources, providing users with the ability to incorporate multiple technologies into the learning process (including distance learning). The ACT Academy in McKinney, Texas, is a K-12 school that has installed an elaborate computer network in order to integrate distance-learning services with the other telecommunications technologies available to its learners. The ACT Academy is a demonstration school funded by a $6 million grant from the U.S. Department of Education. Its charge is to break the mold of conventional instruction using technology-based strategies that promote academic excellence. Each teacher and student in the team of 12-18-year-old students (approximately 100 students) is provided with a laptop computer. The "7-11-year-old team" (180 students) has one portable computer for every 2 students. The "5-6-year-old team" (38 students) uses fixed "docking" stations that provide access to one computer for about every 7 students. Data drops that connect to the computer network are located throughout the school—in classrooms, in hallways, and in the outdoor courtyard. Every classroom has a telephone line, and an Internet node is being established at the school. Students and staff also have access to multimedia computers, printers, CD-ROMs, laser disc players, camcorders, cable TV, on-line services, and distance-learning equipment. The curriculum is project-based and requires students to use all of the tools available to them through the network to work with other students to complete the projects.

An emerging use of computer networking for distance learning is the delivery of integrated voice, video, and data services directly to the desktop. Since 1991, Ford Motor Company has offered university-level courses to employees directly to their desktop computers. Using microwaves, fiber optics, cable, electronic keypads, and telephone links, real-time voice and data exchange is made possible between employees throughout southeastern Michigan and instructors at Wayne State University. Employees access the live, interactive classes using IBM PS/-TV units connected to their office computers, which double as TV monitors. Students hear dialogue just as they would in a classroom, watch the professor or graphic and written information on screen, and use the keypad call button to "raise" their hand. The response feature is an important part of the system; for example, within five seconds, a bar chart can be displayed showing the distribution of answers to an instructor's questions, giving an immediate sense of whether students are grasping a particular concept. After each class, student progress is monitored by the computer; and appropriate remedial lessons are developed. Participants also use telephone conferences and electronic mail as part of the coursework.

According to Ford, employees who have used this system have scored 20 percent higher on examinations than those employees who took the same courses in a traditional classroom setting. The company also found that the increased activity and regular assessment capabilities encourage better preparation, participation, and self-assessment. Among the other benefits are efficient resource use, greater accessibility to learners, and cost reduction. Although significant expenditures were necessary to provide a host computer, site controllers, and keypads, the system has proved efficient. The PS/2-TV units cost less than $500 each and are very easily moved to another desk. Transmission costs are $60 per hour. Ford estimates that most participants save more than 30 hours commuting time per class per semester (Klinck, 1993; Steele, 1993).

Wireless

Using wireless technologies to make the "last link"—to the user—is an emerging, but relatively untested, option for distance learning. PBS is working with the cellular technologies industry to provide the new Mathline service to teachers and learners via wireless communication. Mathline is a full-service interactive data, video, and voice network that plans to offer discipline-based mathematics learning services, professional development opportunities, and electronic forums. Participants in the planned wireless project will be provided with laptop computers and will receive Mathline services, via their local public television station, using cellular communications. The benefits of such projects have not yet been evaluated, but clearly have the potential to address "last-link" problems for learning sites, independent of cable or telephone wires (compiled from materials received from PBS Mathline and the Cellular Telecommunications Industry Association, June 1994).

SUMMARY

The range of distance-learning technologies and services described in this chapter shows several means for providing and receiving di learning services, using technologies that fi singularly and in integrated systems. descriptions enable us to better understa available and anticipated resources for n the needs of learners at all levels of educa prekindergarten through graduate schoo diversity of telecommunications techn used to deliver distance learning and the of integration of these technologies hi the complexities involved in developing sy Despite increasingly rapid changes in tech ical developments, fluctuating price stru and relatively limited data on the use an tiveness of telecommunications techno all levels of education are moving ahea innovative applications of these technolo distance learning.

New challenges and opportunities for improved education have been created by recent federal education legislation and telecommunications industry initiatives. Education legislation not only calls for statewide technology plans, but provides funding support for learning technology planning and implementation. The Goals 2000: Educate America Act and the Improving America's Schools Act, which includes the Technology Education Act of 1994, provide increased funding specifically intended for technology planning and implementation. In addition to the new federal opportunities, states are providing significant amounts of funding to develop statewide infrastructure and distance-learning resources. The Public Broadcasting Service (PBS), cable companies, and telephone companies are investing in infrastructure and content programming. These initiatives provide new challenges for educators to harness the potential of telecommunications resources for the benefit of all learners and to meet the National Education Goals.

Even with these new opportunities and resources and the growing popularity of educational technology, effective distance learning is still a relatively untapped resource with enormous potential to improve learning opportunities. According to Market Data Retrieval (MDR, 1993), only 28 percent of the nation's school districts use some form of distance-learning technologies. Many barriers to its use have been successfully overcome, but many still exist, whether due to lingering past misconceptions or new challenges faced by a rapidly changing field. This chapter examines many of the significant barriers and challenges to effective distance learning and analyzes the ways in which they affect various levels of education and instruction. The issues discussed here do not draw from comprehensive case studies of distance-learning implementation. Rather, this chapter presents a sampling of issues most often noted in research literature, trade publications, and informal discussions with individuals experienced in planning and using distance learning.

INCOMPATIBILITY OF TECHNICAL SYSTEMS

Because distance learning involves an integration of technologies, issues of incompatibility are obviously significant. Increasingly, rapid changes in technology are resulting in incompatibility problems at all levels of distance learning use. The emerging role of digital compression is a good example of this problem. This technological innovation allows for much more efficient use of bandwidth and airtime, but usually involves new equipment for the user and additional transmitting complications for the provider. Some providers such as the National Technological University (NTU) and the Southern Educational Resource Consortium have made comprehensive systemwide changes. NTU has installed new units throughout its system at both origination and downlink sites. Just as is commonly done with Ku- and C-band satellite systems, services are offered in both the old and new formats. Other providers are adopting a more cautious approach because compression protocols vary and standards

Although federal education legislation and NII initiatives are providing new opportunities for distance learning, significant barriers still exist to its effective, widespread use.

have yet to be established. This particular issue is critical, because many major providers, including PBS, intend to incorporate digital compression technology. Community colleges are among the most significant users of satellite networks; for this group, the onset of digital technology presents serious cost and planning obstacles, requiring them to replace or upgrade equipment they had purchased only within the past five years (Monica Pilkey, CCSN, personal communication, December 1993).

Rapid advances are changing telecommunications at all levels, and innovations can often surpass the capabilities of the greater infrastructure. As a result, even in cases where use of distance learning has been well thought out and implemented, long-term goals can meet with incompatibility problems at the telecommunications industry level. The Watagua school district in North Carolina is one such example. Their very successful ISDN network is serving the community's learning and communication needs, but plans to extend the network to link six neighboring counties have proven difficult due to the regional phone network's insufficient signal-switching capabilities (Patty Blanton, Watagua High School, personal communication, June 1994).

INSUFFICIENT USE OF AVAILABLE RESOURCES

Many schools and businesses make little use of available resources for various reasons. On the most basic level, all delivery systems are simply not available everywhere. Though homes and businesses have long been wired for telephones, for example, schools traditionally have not; and because cable television's primary application has been news and entertainment, both schools and businesses were not initially wired. Sharing resources is an obvious option; but without regional cooperation, telecommunications resources may operate in parallel rather than in an integrated fashion. Increasingly, however, communities are beginning to organize their efforts. One of the most popular remedies for limited access to delivery systems seems to be cooperation among schools, colleges, and businesses. The CCSN notes that businesses and associations are currently developing training that uses the facilities of a local community college, approximately 85 percent of which have some access to satellite networks (Monica Pilkey, CCSN, personal communication, December 1993).

Some technologies have evolved haphazardly over many years, prompting distance-learning users to reevaluate functions for underestimated resources. Telephone, for example, which was originally intended to provide only voice communication, now provides video and data delivery as well. Ford Motor Company, whose use of innovative keypad response systems to provide interactivity has been very successful, is nevertheless looking to transfer this response function to computers and telephones. This "return" to the more ubiquitous telephone system will allow their employees to take courses at home, make the services available to nonemployees, and also alleviate the problem of acquiring new keypad hardware (Steele, 1993).

Another common barrier to using resources is an inability to incorporate distance learning into existing instruction. Scheduling within traditional school organization is a significant challenge for K-12 distance-learning use. The rigidity of the school year and school day are often formidable barriers (Tushnet, Bodinger-de Uriarte, Manuel, van Broekhuizen, & Millsap, 1993). Because satellite-delivered programs often do not mesh exactly with the school schedules, such conflicts are difficult to resolve (Barker, 1992). Broadcast television and cable providers are also tied to schedules that conflict with school schedules. Research on distance learning, in fact, often cites issues of time and scheduling as the most significant obstacle (Honey & Henriquez, 1993). Although videotaping courses has been a helpful option, increasing use of interactivity and more collaborative activities surrounding distance-learning programming may diminish the usefulness of delayed viewing.